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A Contribution toward the Life Histories of Two California Shrimps, *Crago franciscorum* (Stimpson) and *Crago nigricauda* (Stimpson)

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INTRODUCTION

The following paper presents a study of the life histories of the two species of shrimp, *Crago franciscorum* (Stimpson) and *Crago nigricauda* (Stimpson), which make up the commercial shrimp catch of San Francisco Bay. Although small defects and a few serious gaps exist in our present knowledge, the material herein presented should be valuable, as it is the only life history study which has been made of these two species.

This investigation has been sponsored by the California Division of Fish and Game through the courtesy of Mr. N. B. Scofield. Certain collecting apparatus have been made available through the cooperation of Mr. W. L. Scofield of the California State Fisheries Laboratory. Invaluable cooperation in obtaining samples from the catch of the commercial fishery was given by Mr. Frank Spenger and his fishermen and by the Chinese camps. The material has been studied at Stanford University under the supervision of Dr. Frank W. Weymouth, Professor of Physiology, and Dr. Willis H. Rich, Professor of Zoology.

History of the Fishery*

The earliest shrimp fishing in San Francisco Bay was done about 1869 by Italian fishermen. The shrimp were taken in seines, 60 feet long by 8 feet deep, with a bag in the center. With this gear they took ample shrimp to supply the demand as well as some fish for the fresh fish market.

In 1871 the Chinese began using the Chinese shrimp net which greatly increased the catch. By 1897 there were twenty-six camps operating on San Francisco Bay. For a time shrimp fishing was carried on also in Tomales Bay but was abandoned a few years prior to 1897. After the Chinese began shrimp fishing, the local market could absorb only a small part of the catch, as the consumption of fresh shrimp was always limited. A profitable export trade, however, was built up on the dried product which was shipped to the Orient.

Agitation against the use of the Chinese shrimp nets soon developed, the contention being that many young fish were destroyed by them, particularly small striped bass in San Pablo Bay. In 1897 and again in 1910, N. B. Scofield investigated the Chinese shrimp fishery for the California Fish and Game Commission. In 1901, as a result of his findings, the Legislature established a closed season to shrimp fishing during the months of May, June, July and August. The Chinese hired attorneys to contest the laws restricting their operations, but in 1911 the use of the Chinese nets was prohibited entirely. In 1915 the Legislature passed a law allowing the use of the Chinese shrimp nets in south San Francisco Bay (District 13). About this time trawl fishing for shrimp started in the northern end of the bay. The trawl fishermen restrict their operations to north San Francisco Bay (District 12) so

* The material on the history of the fishery was taken from Scofield (1919) and Bonnot (1932), where more detailed historical accounts may be obtained.

that catches from Districts 12 and 13 represent respectively the catch made with trawls and that made with the Chinese nets.

Types of Fishing Gear

The trawl fishermen use an 18 to 20 foot beam trawl with a funnel-shaped net about 60 feet long. This is dragged over the bottom in the same direction that the tide is running. A single drag lasts from forty minutes to two hours. A day's work consists of two to four hauls with a total catch of 100 to 1000 pounds of shrimp. For a complete description of the trawl and its operations see Fry (1933).

The Chinese shrimp camps use the Chinese shrimp net, which is funnel-shaped, being 30 feet across the mouth and 40 feet in length. Each camp operates 20 to 50 nets. These are held stationary by a system of lines and anchors while the tide carries the shrimp into them. The nets are set and fished during a single tide, either ebb or flood, and are lifted just before the tide turns. A day's catch for one camp varies from 400 to 8000 pounds. A detailed account of the operation of the Chinese net is given by Bonnot (1932).

Species in the Catch

The shrimp fishery of San Francisco Bay depends entirely on the genus *Crago* (the *Crangon* of earlier writers) thus most closely resembling that of the North Sea. Three species are taken, *Crago franciscorum, C. nigricauda* and *C. nigromaculata,* although the last is of very slight importance.

C. franciscorum, because of its larger size, forms the bulk of the shrimp that are marketed fresh. It ranges from southeastern Alaska to San Diego, California. The females reach a length of 80 mm., the males about 60 mm. It may be distinguished from *C. nigricauda* by the shape of the chela or hand which is long and narrow, averaging four and a half times as long as broad. The dactyl, when closed, lies nearly longitudinal to the chela.

Crago nigricauda closely resembles *C. vulgaris,* the form supporting the shrimp fishery of the North Sea, in fact it was by some early writers considered as a variety of *C. vulgaris.* The females reach a length of 60 mm., the males of 45 mm. The chela in contrast to *C. franciscorum,* is only a little more than twice as long as wide, and the closed dactyl lies almost at right angles to the chela.

The far less abundant *C. nigromaculata* resembles *C. nigricauda,* the chela being similar in proportion. It may be distinguished by the conspicuous round blue spot, encircled by black and yellow rings, on the lateral surfaces of the sixth abdominal segment.

In both *Crago franciscorum* and *C. nigricauda,* the sex can be determined easily in the larger shrimp by the structure of the inner ramus of the first pleopod or abdominal leg. This, in the female, is somewhat flattened and is as long or longer than the inner rami of the following pleopods. In the male the inner ramus of the first pleopod is round and small, being about half as long as the inner rami of the other pleopods. This character has been used for sexing all *C. franciscorum* above 37.0 mm. and all *C. nigricauda* above 27.0 mm. Beneath

these sizes the sex character was not always distinct and all of these smaller shrimp have simply been referred to as "immature."

Data and Methods

Localities Fished

Samples from the commercial shrimp fishery were taken periodically from June, 1931, to June, 1933. The trawl fishermen operate principally in two localities: off Pt. San Quentin between California Pt. and the Marin Islands; and on "Chicken Creek Flats," north of Pt. San Pedro (see map, Fig. 1). These two localities hereafter will be referred to respectively as "San Quentin" and the "Flats." Some fishing is done on Southampton Shoals and north of the Key Route Pier at Berkeley. The Chinese shrimp beds are located north of Hunters Point (Pt. Avisadero) and south of Oakland Creek, with the exception of two beds a few miles south of Hunters Pt.

The material on young shrimp was collected by the writer with a 5½ ft. beam trawl of the sled-frame type. The net was made of bobbinet with a section of an old commercial net used as a protective outside covering. Between September, 1932, and May, 1934, many hauls were made with this net in a variety of depths and locations in south San Francisco Bay south of San Mateo Bridge. Several collecting trips were also made to San Pablo Bay, Suisun Bay, and the lower tidal portions of the San Joaquin River as far up as the mouth of Middle River which, by water, is about 18 miles above Antioch and 15 miles below Stockton.

Methods and Measurements

The total length of each specimen was measured from the tip of the rostrum to the tip of the telson. This measurement was made with a vernier caliper to the next lower 0.1 mm. The larger shrimp were held in the fingers when measuring; the smaller ones—under 37.0 mm. for *Crago franciscorum* and under 31.0 mm. for *Crago nigricauda*—were held against a flat surface. The latter method of measurement averaged 0.3 mm. longer at 37.0 mm. and 0.2 mm. longer at 31.0 mm. than when the specimen was held in the fingers.

The samples were tabulated in two-millimeter groups. They were then grouped by months, and graphs were made showing the frequency with which each length occurred.

General Features of the Life Histories

The general features of the life histories of both *Crago franciscorum* and *C. nigricauda* are similar to those found by Ehrenbaum (1890) for *C. vulgaris,* which supports the shrimp fishery of the North Sea. He found that the eggs hatched in water of high salinity, and that the larval stages occur floating in the plankton. The earliest post-larval shrimp are found, however, at a considerable distance from the ocean in the brackish or nearly fresh water of shallow tidal flats or sloughs. As the young shrimp develop, they move into deeper water of increased salinity, gradually entering the commercial catch.

Ehrenbaum considered that there were two spawning seasons. Our data, on *Crago franciscorum* and *C. nigricauda,* indicate a single but

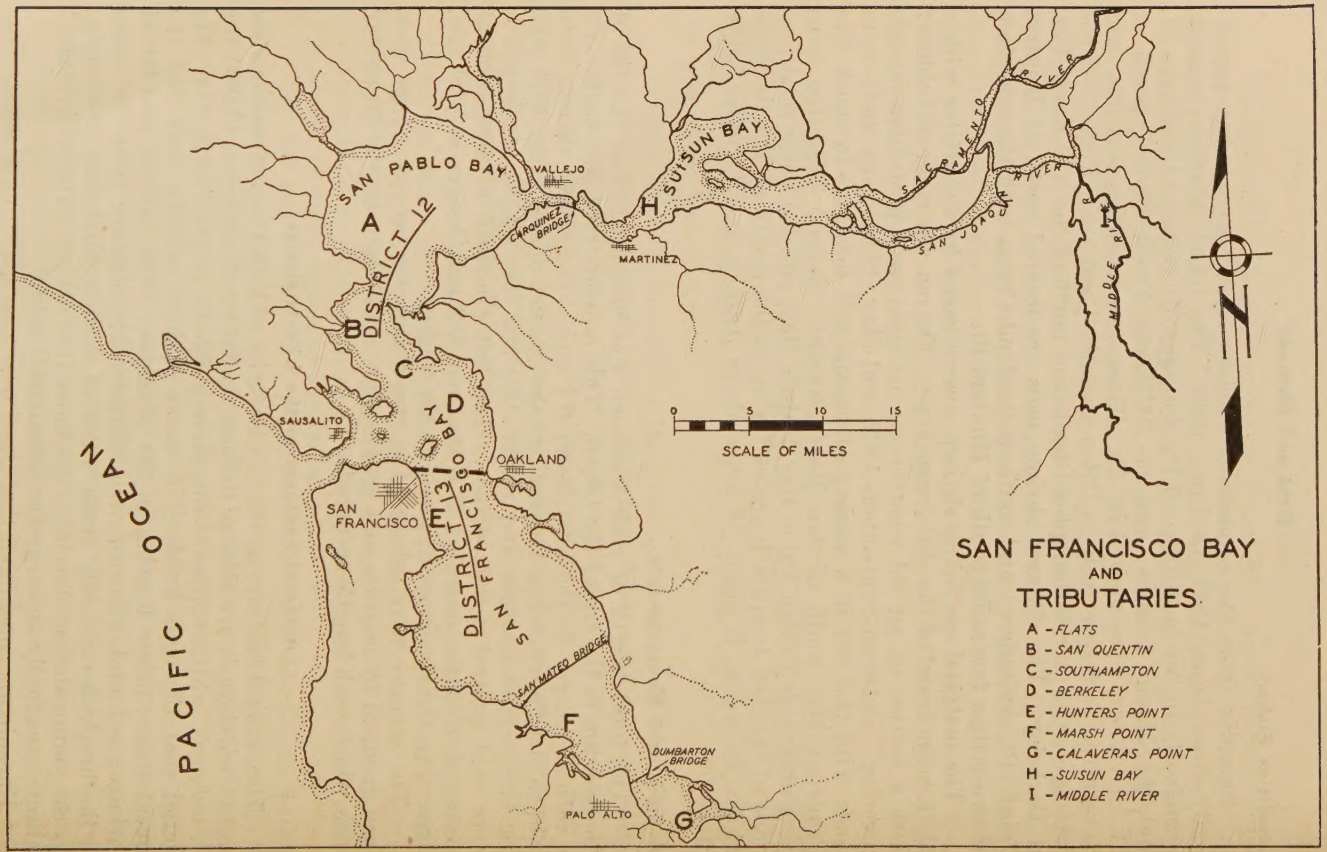

Fig. 1. Map of San Francisco Bay and the lower San Joaquin River.

very extended breeding season. This will be discussed after the material on these species has been presented.

Ehrenbaum considered that *C. vulgaris* attained an age of three or four years. The data on the California species of *Crago* indicate that they disappear from the commercial catch soon after they are a year old. Further discussion of this will be postponed until our material has been presented and analyzed.

The main differences in the life histories of *Crago franciscorum* and *Crago nigricauda* are that the spawning seasons occur at different times and that *Crago franciscorum* ranges into areas of lower salinity. Of the two the development of *C. nigricauda* more nearly parallels that of *C. vulgaris,* as would be suspected by its closer systematic relationship.

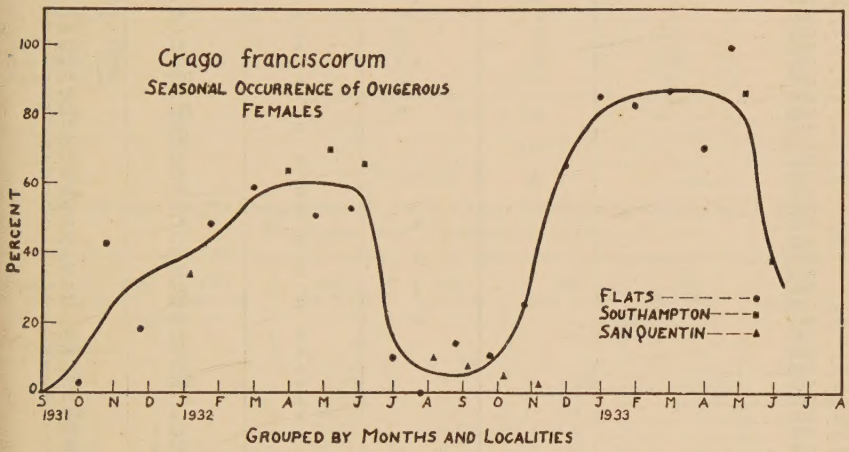

Fig. 2. *Crago franciscorum,* percentage ovigerous among mature females, San Francisco Bay, September, 1931, to June, 1933.

ANALYSIS OF DATA ON CRAGO FRANCISCORUM

Breeding Season

Shrimp of the genus *Crago* carry their eggs under the abdomen attached to and between the basal joints and inner rami of the pleopods or abdominal legs. The main spawning season for *Crago franciscorum* extends from December to May or June, inclusive, but some ovigerous or egg-bearing females may be found in any month of the year. Females carrying eyed eggs occur in seven months of the year, from December to June.

Examination of 338 ovigerous females taken throughout the year showed that only 3 or 0.9 per cent were under 53.0 mm. in length. On this basis all females of 53.0 mm. or more have been considered mature. Table 1 and Figure 2 show the percentage of mature females that were ovigerous from September of 1931 to June of 1933. From August, 1932, to October, 1932, inclusive, the percentage of ovigerous females in each sample varies from zero to 14. November shows an increase but the average percentage is still low. From December, 1932, to April, 1933, the percentage varies from 66 to 87. Two samples in May give 100 per cent and 87 per cent, but the total number of mature females

examined was only 5 and 15, respectively. In June there is a drop to 39 per cent. Although the main breeding season is confined to six or seven months, it is significant that ovigerous females are found in some locality in every month of the year.

TABLE 1

Percentage of mature females of *Crago franciscorum* that are ovigerous, San Francisco Bay, September, 1931, to June, 1933

	Locality			Number of mature females	Percentage ovigerous
	Southampton	San Quentin	Flats		
Sept., 1931		x		1	0.0
Oct., 1931			x	41	2.4
Nov., 1931			x	7	42.8
Dec., 1931			x	11	18.2
Jan., 1932		x		94	34.1
Feb., 1932			x	109	48.6
Mar., 1932			x	77	59.7
Apr., 1932	x			144	64.6
May, 1932			x	25	51.9
May, 1932	x			62	70.9
June, 1932			x	13	53.8
June, 1932	x			42	66.7
July, 1932			x	57	10.5
Aug., 1932			x	17	0.0
Aug., 1932		x		37	10.8
Sept., 1932			x	21	14.3
Sept., 1932		x		25	8.0
Oct., 1932			x	28	10.7
Oct., 1932		x		21	4.8
Nov., 1932			x	35	25.7
Nov., 1932		x		40	3.0
Dec., 1932			x	47	66.0
Jan., 1933			x	98	85.7
Feb., 1933			x	97	83.5
Mar., 1933			x	225	87.5
April, 1933			x	121	71.1
May, 1933			x	5	100.0
May, 1933	x			15	86.7
June, 1933	x			31	38.7

Many females bearing eyed eggs occur from December to June. From July, 1932, to November, 1932, no females bearing eyed eggs were taken with the exception of three individuals in August and September. Between December, 1932, and June, 1933, many eyed eggs were found. Since the eggs hatch fairly soon after the eyes become clearly visible, it is reasonably certain that eggs are hatching over a period of approximately seven months.

Some females undoubtedly spawn twice, the second set of eggs being laid after the first set hatches, with one molt intervening. In some shrimp that are carrying eggs (usually in the eyed stage) or empty egg cases, it is found that the ovaries, instead of being spent, contain ripe eggs. It is logical to assume that these shrimp spawn a second time.

Young Shrimp

Very few data are available at this time on the larval stages. It is only known that the eggs hatch in deep water of high salinity and that the larval stages are found floating in the plankton.

After leaving the last free-swimming larval stage, the shrimp assume the adult form and mode of life on the bottom of the bay. The post-larval shrimp from 7 to 15 mm. in length are found at some distance from the ocean in comparatively shallow water of lower salinity

than that in which the eggs hatched. The young occur most abundantly in depths of less than 15 feet on both shell and soft grey silt bottoms, although there seems to be a preference for the mud bottom. As the shrimp grow, they move steadily into deeper water so that samples taken at the same time but from different depths represent different populations, varying slightly in length and age.

TABLE 2

Number of young *Crago franciscorum* in samples from south San Francisco Bay, February to June

	Immatures	Males	Females	Total
Feb. 1–15, 1934	5	143	9	157
Mar. 16–31, 1934	86	0	0	86
April 1–15, 1934	507	4	12	523
April 16–30, 1934	245	4	32	281
May 16–31, 1934	71	7	137	215
June 1–15, 1933	66	121	21	208
Totals	980	279	211	1,470

TABLE 3

Percentage length frequencies of young *Crago franciscorum* from south San Francisco Bay, February to June

Length in mm. (mid-value of class)	1934 Feb. 1–15	1934 Mar. 16–31	1934 April 1–15	1934 April 16–30	1934 May 16–31	1933 June 1–15
Immatures						
6.0			2%			
8.0		2.3%	4.0	4.3%		
10.0		5.8	3.1	3.6		
12.0		18.6	2.5	1.4		
14.0		23.3	2.9	1.8		
16.0		10.5	2.9	.7		
18.0		14.0	2.7	1.8	.9%	
20.0		3.5	4.7	1.4	.9	
22.0		9.3	8.0	6.0	1.9	1.9%
24.0		7.0	11.9	6.8	4.2	2.9
26.0		4.7	15.5	11.4	3.7	4.3
28.0		1.2	12.4	7.8	2.3	4.8
30.0			10.7	11.7	3.3	3.4
32.0	.6%		8.8	12.4	5.1	6.2
34.0	1.3		4.2	9.2	7.0	1.9
36.0	1.3		2.5	6.8	3.7	6.2
Males						
38.0	10.2		.8	1.1	.9	13.0
40.0	19.1				.9	17.8
42.0	22.9				1.4	13.5
44.0	21.7					4.8
46.0	10.0			.4		2.4
48.0	5.1					2.4
50.0	1.9					2.9
52.0	.6					1.0
54.0						.5
Females						
38.0	.6		.8	4.3	5.6	.5
40.0	1.9		.4	2.1	5.1	2.4
42.0	.6		.2	2.5	8.4	
44.0			.4	1.4	7.4	1.0
46.0	1.3		.2	.7	9.3	1.4
48.0	.6		.2		11.2	1.0
50.0	.6				6.0	2.4
52.0					6.5	.5
54.0					3.3	1.0
56.0					.9	
58.0				.4		
60.0			.2			

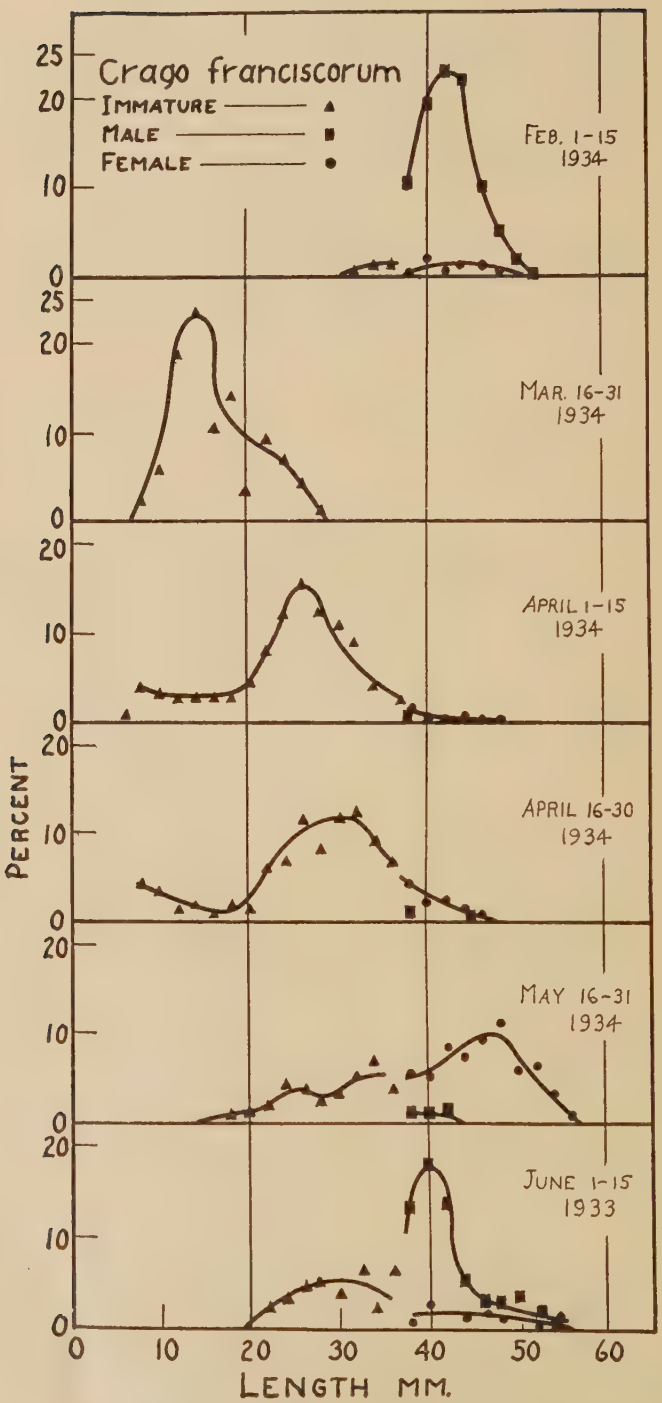

Fig. 3. *Crago franciscorum*, percentage length frequencies of young shrimp from south San Francisco Bay, February to June.

Length frequencies of the young shrimp, taken in south San Francisco Bay south of San Mateo Bridge (see map, Fig. 1, locality F) are given in Tables 2 and 3 and are shown graphically in Figure 3. The following discussion is based upon these data.

All of the shrimp examined were divided into three groups—males, females, and immatures. It was found difficult to sex specimens of *Crago franciscorum* a little below 37.0 mm. so that all of them beneath this size have been referred to as immatures. This length is far below that of the smallest mature females and slightly below that of the smallest mature males.

A small series of young *Crago franciscorum* was taken in south San Francisco Bay on March 27, 1934. Their modal length was at 14 mm., and the range extended from 7 to 29 mm. During April 1-15, 1934, many young shrimp were collected, showing a clearly defined mode at 26 mm. The upper limit of the curve extends in a long skew to 49 mm. but it is possible that the larger individuals are from late spawning in the previous year. The smallest size taken was a single specimen, 6.9 mm. in length. Many young shrimp were taken between 7.0 and 8.9 mm. This would indicate that the shrimp are about 7.0 mm. when they leave their last larval stage. The frequency curves for both the first and latter parts of April show a tendency to rise at their lower ends, which indicates that many shrimp are still present in the larval stages although a large percentage is now changing into the post-larval form. During April 16-30, 1934, the upper end of the curve is at 47 mm. It appears probable that most, if not all, of these larger shrimp result from the earlier part of this year's spawning rather than from that of the previous year.

During May 16-31, 1934, the range is from 17 to 57 mm., with the modal length in the female group at 48 mm. It is to be noted that there is no longer an influx of young shrimp from the larval stages and that the lower limit has drawn well away from the smallest post-larval size. In a sample taken June 6, 1933, the range extends from 22 mm. to 55 mm. with the mode in the male group at 40 mm.

The percentages of shrimp below 29.0 mm. are given in the following table.

TABLE 4

	Percentage under 29.0 mm.
March 16-31, 1934	100.0
April 1-15	81.4
April 16-30	58.4
May 16-31	17.2
June 1-15, 1933	13.9

In March, 1934, all of the shrimp are under 29.0 mm., whereas in the first half of April, 81 per cent are of this size. From this point, the percentage under 29.0 mm. in length diminishes steadily down to 17 per cent in May.

Commercial Catch

The commercial catch, although selective both as regards the size of shrimp taken and the locality fished, gives us our best picture of the shrimp population as a whole. Tables 5 and 6 and Figure 4 present the data secured from monthly samples of the commercial catch of *Crago franciscorum* taken by the trawl fishermen from July, 1931, to June, 1933. That which follows is a discussion based upon these data.

TABLE 5

Number and percentage of immature, male and female *Crago franciscorum* from San Francisco Bay, July, 1931, to June, 1933

	Localities			Total number	Percentages		
	Southampton	San Quentin	Flats		Immatures	Males	Females
July, 1931			x	309	15.2	60.5	24.3
Aug., 1931			x	102	4.9	50.0	45.1
Aug., 1931		x		30	10.0	80.0	10.0
Sept., 1931		x		194	4.1	75.7	20.1
Oct., 1931			x	452	0.4	80.8	18.8
Nov., 1931			x	184	0.5	89.2	10.3
Dec., 1931			x	72	2.7	58.4	38.9
Jan., 1932		x		249	0.4	28.5	71.1
Feb., 1932			x	184	1.1	30.4	68.5
Mar., 1932			x	422	2.7	71.6	25.6
April, 1932	x			192	0.5	21.8	77.6
May, 1932			x	310	36.1	49.4	14.5
May, 1932	x			112	3.6	24.1	72.3
June, 1932			x	162	12.9	65.4	21.6
June, 1932	x			251	2.4	66.9	30.7
July, 1932			x	379	6.3	50.7	43.0
Aug., 1932			x	184	20.6	30.4	48.9
Aug., 1932		x		397	4.3	62.7	33.0
Sept., 1932			x	96	2.1	61.5	36.4
Sept., 1932		x		280	1.4	81.5	17.1
Oct., 1932			x	119	1.7	68.1	30.2
Oct., 1932		x		391	1.5	71.6	26.9
Nov., 1932			x	208	1.0	76.4	22.6
Nov., 1932		x		218	0.9	58.7	40.4
Dec., 1932			x	386	0.0	85.0	15.0
Jan., 1933			x	387	0.0	64.6	35.4
Feb., 1933			x	365	0.0	68.2	31.8
Mar., 1933			x	394	0.3	38.1	61.7
April, 1933			x	371	24.0	31.0	45.0
May, 1933			x	180	40.0	26.1	33.9
May, 1933	x			65	7.7	35.4	56.9
June, 1933	x			171	8.8	37.4	53.8
Grand total				7,816			

In 1932 a few individuals below 35.0 mm. occur in March and April. In May, 1932, the immature group makes up 36 per cent of the samples taken on the Flats. Small shrimp continue to appear in appreciable numbers until September. The appearance of the immature group is essentially the same as in 1932, except that in April, when the fishermen were working on the Flats, 24 per cent of the catch was in the immature group whereas in April of 1932, when the fishing was all done on Southampton Shoals, the young shrimp constituted only 0.5 per cent of the catch.

In 1932 the incoming male group first appears in May. The modal length is then at 40 mm., from which point it advances up to 47.0 mm. in September and November. Then there occurs a slight regression back to 45 mm. in January, 1933. From here the mode advances up to 48 mm. in April.

The male group is not bimodal at any time in the spring of 1932. The older males occur as the modal group for the last time in April. The incoming males occur for the first time in May.

In 1933 the males show two distinct modes in April. The greatest number of the older males then falls at 48 mm. whereas the mode for the incoming group is at 38 mm. or less. By May the majority of the older male group has disappeared from the catch. In June the modal length of the incoming male group has not yet advanced past 39 mm.

TABLE 6

Percentage length frequencies of *Crago franciscorum* from San Francisco Bay, July, 1931, to June, 1933

	1931						1932												1933					
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Localities—																								
Southampton										x	x	x											x	x
San Quentin		x	x				x							x	x	x	x	x						
Flats	x	x		x	x	x		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	
Length in mm. (mid-value of class)																								
Immatures																								
22.0											.5%											3%		
24.0											.2											.8	.4%	
26.0	.3%										1.7				.2%							1 1	2.4	.6%
28.0	1.0								.5%		2.6	.5%										2 2	2.9	
30.0	1.3	.8%				1.4%			.2	.5%	4.0	.7		.3								2 7	1.6	
32.0	2.9			.2%					.7		3.6	.5	1.8%	1.0			.2%				.3%	1 6	2.9	1.8
34.0	3.9	1.5	.5%	.2					.7		7.6	2.2	1.3	2.9	.2	.8%						5 4	9.4	3.5
36.0	5.8	3.8	3.6		.5%	1.4	.4%	1.1%	.7		7.3	2.7	3.2	5.0	1.1	.8	.7					10 0	11.8	2.9
Males																								
38.0	14.9	3.8	2.1	1.8	.5		1.2	2.7	2.1		10.2	6.1	4.0	4.8	.8	1.2	.2		1.0%		.3	4.9	7.8	11.1
40.0	15.5	3.8	8.8	2.6	3.8	5.5	1.6	9.2	4.7	1.0	16.1	11.4	7.1	5.7	1.1	2.7	2.1	1.6%	2.1	3.6%	1.0	4 3	4.5	9.9
42.0	16.5	6.1	10.3	6.4	8.2	8.3	2.8	5.4	8.1	1.0	10.0	22.5	12.7	7.4	6.4	5.9	8.0	8.5	10.1	10.7	5.3	2 4	8.2	8.8
44.0	8.4	9.1	19.1	9.7	10.3	12.5	8.0	4.9	11.9	1.0	3.6	15.7	9.5	8.1	11.4	12.2	11.3	18.1	17.3	17.8	9.6	3 5	2.4	2.3
46.0	3.2	12.9	11.9	13.3	14.7	2.8	7.2	2.7	14.6	2.6	.7	7.0	10.0	8.1	17.8	18 8	14.6	19.4	14.2	18.6	9.9	4 3	1.6	3.5
48.0	1.3	10.6	13.9	13.1	19.6	13.9	5.6	1.6	11.6	4.2	.9	2.0	5.8	8.1	17.0	15.3	13.6	13.7	10.1	10.4	5.1	5 7	.8	.6
50.0	.3	6.8	5.7	11.1	15.2	6.9	.8	1.6	9.0	3.1	.7	1.0	1.3	5.7	11.2	8.0	8.0	13.2	5.9	3.8	3.8	2 4	.4	.6
52.0	.3	2.3	2.6	10.0	8.7	2.8		1.1	5.5	2.1		.2	.3	3.1	5.9	4.5	6.1	6.5	3.1	2.5	2.0	2 4	1.6	
54.0		.8	1.0	7.1	4.9	1.4	.8	.6	2.6	3.6	.5			1.2	3.5	1.8	1.9	2.6	.5	.5	.8	1 1	.8	.6
56.0			.5	4.0	1.6	1.4		.6	.9	1.0				.3	1.1	.2	1.6	1.3	.3	.3				
58.0		.8		1.3	1.6	2.8			.2	1.0		.5			.2	.2					.3			
60.0				.4			.4		.2	1.0													.4	
62.0									.2															
Females																								
38.0	.3	.8	3.6	.7		1.4	.8		.9		1.9	.7	3.2	3.1	.8	.8	.9		.3			2 2	5.7	4.1
40.0	2.3	.8	2.1	.9			1.2	.6	.7		.7	.7	3.2	4.1	2.4	2.5	.7		.8	.3		1 6	3.7	2.3
42.0	1.6	3.0	3.1	.9	2.2	2.8	4.8	2.2	.5		.9	1.0	4.7	3.1	1.9	3.9	3.5	1.0	2.6	1.4		2 7	6.1	2.9
44.0	1.6	1.5	4.1	1.1	2.2	5.5	2.0	1.6	.9	.5	1.9	3.4	3.4	3.8	1.1	2.9	1.4	.5	2.3	.8	.3	2 2	4.1	5.8
46.0	1.0	1.5	1.0	2.0	.5	4.2	6.4	1.1	.9	.5	2.1	1.7	3.2	4.1	.2	3.1	2.6	.5	1.3	1.1	1.0	8	4.9	4.7
48.0	1.9	1.5	1.5	1.5	.5	4.2	4.4	.6	.9		.5	1.0	5.5	4.0	1.6	2.2	1.9	.5	1.3		.5	5	4.9	3.5
50.0	2.6	1.5		2.0		1.4	4.8	.6	1.4			2.7	3.7	3.8	1.3	.6	1.4	.3	.5	.5	1.8	1 3	1.2	5.8
52.0	1.6	4.5	1.0	.7	1.1	4.2	8.9	2.7	.9	2.1	1.2	2.7	3.7	2.8	.5	2.0	1.6		1.0	1.1	1.0	1 1	1.2	6.4
54.0	1.3	3.0	.5	.4	.5	5.5	5.6	5.4	1.7	4.2	2.1	2.2	4.7	3.1	1.9	2.0	2.1	1.6	3.6	3.3	7.1	1 6		5.3
56.0	4.2	7.6		1.3	.5	4.2	8.9	6.5	2.6	4.2	1.4	2.4	1.6	2.1	.2	1.2	4.0	1.8	2.6	4.4	6.6	1 6	1.6	3.5
58.0	1.9	3.0	.5	.9			6.0	13.0	1.7	4.2	2.4	1.5	1.6	1.0	2.7	1.0	2.1	.8	3.4	5.5	10.9	4 3		2.3
60.0	2.6	3.8	1.0	.7		1.4	5.6	12.5	3.3	7.8	3.3	1.5	2.6	1.0	1.1	.8	3.1	2.6	4.7	4.4	10.7	4 9	1.6	1.2
62.0	.6	4.5	.5	1.3			6.8	6.5	2.4	5.7	2.4	1.5	.8	1.2	2.1	1.8	1.2	1.6	2.8	3.3	6.6	5 1	.8	.6
64.0	.6			1.8	1.1	2.8	2.4	4.3	.9	6.2	2.8	1.2	.3	.7	1.9	.8	1.2	1.3	1.3	1.9	3.8	5 9	1.8	1.8
66.0			1.0	1.5	1.1			3.8	2.8	7.8	1.2	.7	.5		.8	1.2	.5	1.6	2.8	1.6	5.3	3 8	2.0	.6
68.0				.9		1.4	.4	3.8	.5	3.6	1.4	1.2			1.3	.4	2.1	1.6	1.6	1.1	2.8	2.2	.8	1.2
70.0				.2			1.2	1.6	.7	8.9	.9		.3	.2	.2	.2	.7	.3	1.0	.5	1.8	1 3		1.2
72.0							.4	.6	.2	7.8	.5	.7				.4	.2	.3	1.3	.5	.8	1.6	1.2	
74.0					.5			1.1	.5	9.0	1.2	.2							.3		.5			
76.0							.4		.5	3.6	.9	.2									.3			.6
78.0									.2	1.0														
80.0									.2													3		
82.0										.5														

In 1932 the incoming female group first enters the commercial catch in appreciable numbers in May. It then extends from perhaps as high as 48 mm. down into the immature group. In June the incoming and older groups appear to overlap heavily. By July the major portion of the older group has disappeared. The incoming females have a modal length at about 48 mm.

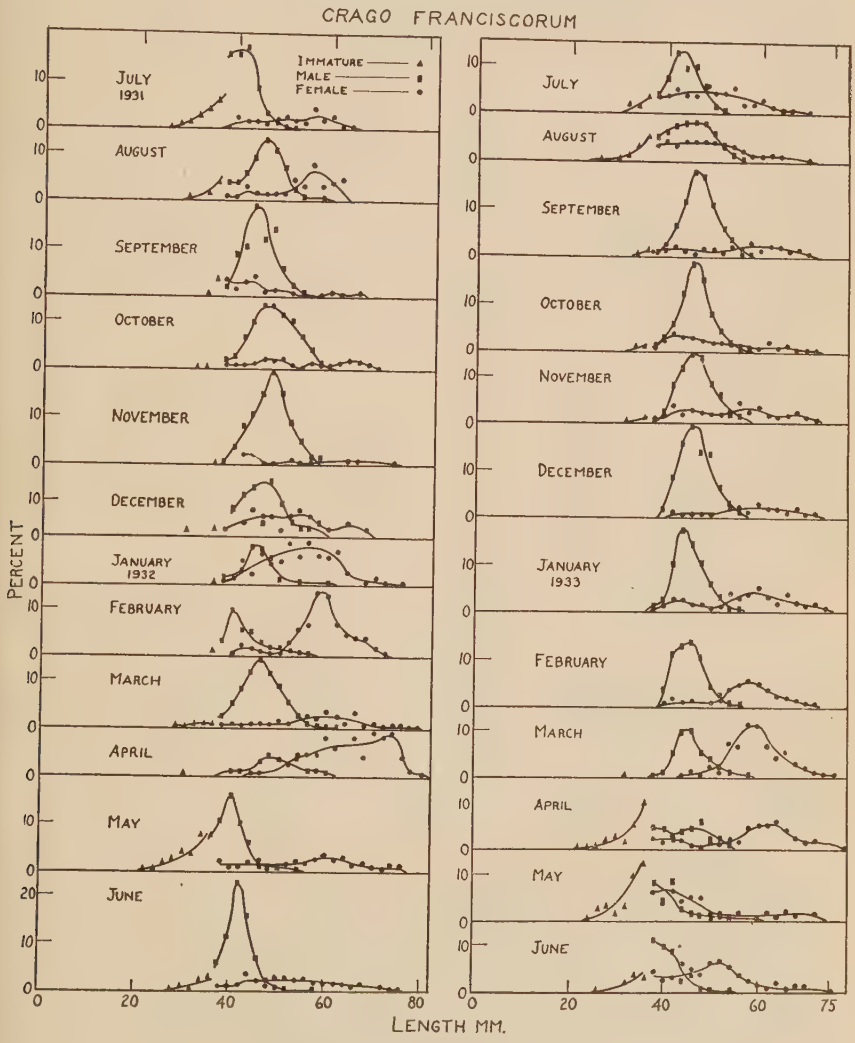

Fig. 4. *Crago franciscorum*, percentage length frequencies from San Francisco Bay, July, 1931, to June, 1933.

From September to December the range presented by the females is very extensive and there is no sharply defined mode. In September and October there are small modes at 41 mm. and 43 mm., respectively. In November and December small modes appear at 57 mm. and 59 mm., respectively. In January of 1933 there is a preponderant mode at 60 mm. although a smaller mode occurs at 43 mm. In February the modes

are present at 43 and 58 mm. and the upper is again strongly dominant. In March the females show a fairly sharp single mode at 59 mm. This jumps to 64 mm. in April but at this time an incoming female group presents a mode at 38 mm. or less. The larger females have fallen off heavily in number from the commercial catch in May, but show as a distinct group with a mode at about 66 mm. The principal modal length of the females is represented by the incoming group at 42 mm. By June the older females have disappeared as a group and although many of them still occur, they are overlapped heavily by the larger members of the incoming group.

In March of 1932 the females have a modal length at 60 mm. This reaches the unusually high point of 73 mm. in April. The mode has fallen back to 61 mm. in May, by which time the incoming female group is occurring in large numbers. Many members of the older group are still found in June but they now are overlapped heavily by the larger members of the incoming group as in June of 1933. After this time the older females disappear from the catch as a group and are subsequently represented by occasional individuals only.

The females grow far more rapidly than the males and attain a much larger size. In July of 1932 the females have a modal length at 48 mm. whereas the males have a modal length at 43 mm., a difference of 5 mm. or nearly 10 per cent. By March of 1933 when each group shows a single sharp mode, it is at 59 and 45 mm., respectively, for the females and males, a difference of 14 mm. or nearly 25 per cent. The largest female examined was 82 mm., whereas the largest male was 62 mm., a difference of 20 mm. or 25 per cent.

In October, 1931, a series of *Crago franciscorum* was taken in the lower San Joaquin River as far up as the mouth of Middle River. This series had a maximum size at 34.0 mm. and a minimum at 14 mm. In November, 1933, another series taken in upper Suisun Bay and the lower San Joaquin River as far up as Antioch Bridge had modal lengths of 32 for the immature group, which ranged down to 17 mm., and a modal length of about 40 mm. for the males. The occurrence of such a large number of small shrimp at this time of year helps to explain the long period over which small shrimp enter the commercial catch.

The ratio of males, females, and immatures shows a definite cycle in *Crago franciscorum*. The percentage of males, females, and immatures occurring each month in the different localities are given in Table 5. In order to show more clearly the trend, the percentages in different localities in the same months were averaged and then a moving average by three's was calculated and the result is shown in Figure 5. The females appear in greatest abundance between December, 1931, and May, 1932. This corresponds roughly with the breeding season. The males occur in greatest numbers between August and December, 1931, which is the period just preceding the breeding season. This same general cycle occurs the following year although it is slightly retarded for both sexes. The immature group occurs in greatest numbers between April and August and nearly disappears from the catch between November and February.

No evidence has appeared for either species to indicate that a reversal of sex (from males to females) takes place, as Berkeley (1929) considered occurred in the genus *Pandalus*.

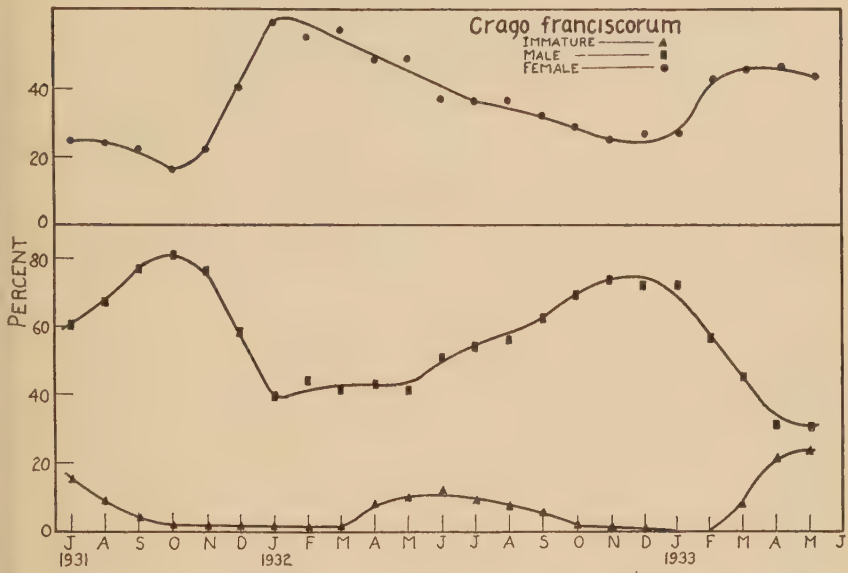

Fig. 5. *Crago franciscorum*, percentages of immature, male and female shrimp from San Francisco Bay, July, 1931, to June, 1933.

ANALYSIS OF DATA ON CRAGO NIGRICAUDA

Breeding Season

Crago nigricauda, which is considerably smaller than *C. franciscorum*, forms at certain times the largest part of the commercial catch. The fishermen call *C. nigricauda* "deepwater," "black-tailed" and "black" shrimp.

The spawning season extends from the spring through the summer and into the fall. All females 37.0 mm. or longer were considered to be mature after an examination of 900 ovigerous females had shown only four, or less than one-half of one per cent, to be mature under that length. Table 7 and Figure 6 show the percentage of mature females found to be ovigerous for each month between August, 1931, and June, 1933. From November, 1931, to February, 1932, there is a variation from 15 to 8 per cent. The appearance in March, 1932, of 28 ovigerous females, representing 21 per cent of those that are mature, marks the beginning of the spawning season. Between April and September, 1932, with the exception of two samples from the Flats, the percentage of ovigerous females varies from 44 to 78. In October a sample from the Golden Gate Shrimp Company, a Chinese camp at Hunters Point, has 16 per cent, or 10 ovigerous females, and a sample from San Quentin Point has 28 per cent, or 36 ovigerous females. In November no ovigerous females were found at the Flats and only one (3.7 per cent) at San Quentin. Some ovigerous females can be found at

any month of the year, and the main breeding season lasts at least six months, from April to September, inclusive. (Table 7 and Figure 6.)

TABLE 7

Percentage of mature females of *Crago nigricauda* that are ovigerous, San Francisco Bay, August, 1931, to June, 1933

	Locality					Number of mature females	Percentage ovigerous
	Flats	San Quentin	South-ampton	Berkeley	Hunters Point		
Aug., 1931		x				71	56.4
Sept., 1931		x				144	69.4
Oct., 1931	x					63	36.5
Nov., 1931	x					69	13.0
Dec., 1931	x					20	15.0
Dec., 1931				x		37	10.8
Jan., 1932	x					63	12.7
Jan., 1932		x				93	9.7
Feb., 1932	x					53	9.4
Feb. 1932		x				26	7.7
Mar., 1932	x					133	21.0
April, 1932	x					134	44.1
May, 1932			x			156	62.2
June, 1932			x			119	78.2
July, 1932	x					55	5.6
July, 1932					x	106	67.9
Aug., 1932	x					51	3.9
Aug., 1932		x				212	46.7
Sept., 1932		x				128	66.4
Oct., 1932					x	61	16.4
Oct., 1932		x				129	27.9
Nov., 1932	x					3	0.0
Nov., 1932		x				27	3.7
Dec., 1932	x					38	7.9
Jan., 1933	x					56	5.4
Feb., 1933	x					75	13.3
Mar., 1933	x					76	32.9
April, 1933	x					46	6.5
May, 1933	x					20	25.0
May, 1933			x			22	72.7
June, 1933			x			66	87.8

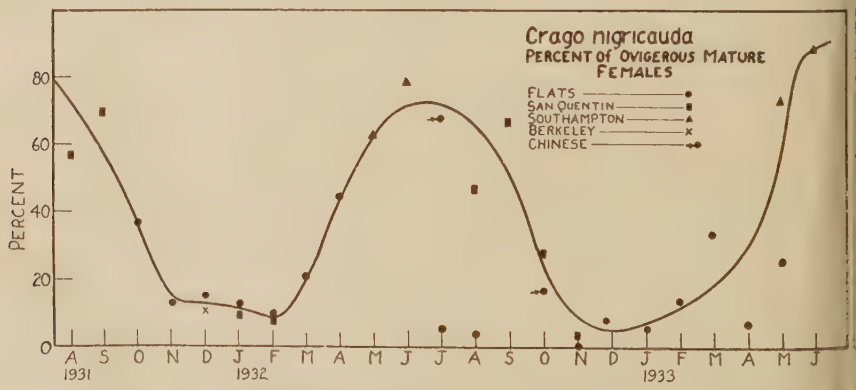

Fig. 6. *Crago nigricauda*, percentage of ovigerous among mature females, San Francisco Bay, August, 1931, to June, 1933.

On the Flats in July, 1932, only three (5.6 per cent) ovigerous females were taken. Again in August only two (3.9 per cent) were obtained at this locality. The Flats are farther from the ocean than any other of the fishing areas. Apparently as the eggs develop, the

shrimp seek water of higher salinity, since at this same time other areas (Hunters Pt. and San Quentin Pt.) nearer the ocean yield large numbers of ovigerous shrimp. Had no fishing been done in these other areas, it would appear as though there were two breeding seasons, with the months of July and August intervening. It is suggested that this might account for Ehrenbaum's conclusion that *Crago vulgaris* has two breeding seasons, separated by about a month and a half in the late summer; either that the fishermen move away from the ovigerous shrimp or that the ovigerous shrimp move out of the area of fishing operations.

Some females appear to spawn twice, as was found to be the case with *C. franciscorum*. It is not unusual to find females, whose ovaries are distended with ripe eggs, carrying eggs or empty egg cases under the abdomen. There is little doubt that such females spawn a second time.

Young Shrimp

Very few data are available on the larval stages. Their development is doubtless very similar to that shown by Ehrenbaum (1890) for *C. vulgaris*. The eggs hatch near the ocean in water of high salinity and the larval forms appear as floating members of the plankton population.

The post-larval shrimp are taken at a considerable distance from the ocean in the shallow water of tidal flats and sloughs. The young shrimp under 15 mm. in length occur on both soft grey silt and shell bottoms, and usually at a depth of less than 20 feet. Although they are more abundant in shallow water, they range into deeper water than do the young of *C. franciscorum*.

Tables 8 and 9 and Figure 7 give the data on a series of samples of young shrimp taken at Calaveras Pt. at the southern end of San Francisco Bay (see map, Fig. 1, locality G). These hauls were made at a depth of 2 to 18 feet on a bottom varying from soft grey silt to shell and sand. All *Crago nigricauda* of 27.0 mm. or longer were sexed. Beneath this size, sexing was difficult and unreliable and these indi-

TABLE 8

Number of young *Crago nigricauda* in samples from South San Francisco Bay, November, 1933, to April, 1934*

	Immatures	Males	Females	Total
Nov., 1933	314.5	10.0	7.5	332
Dec., 1933	316.5	10.0	2.5	329
Jan., 1934	262	24	18	304
Feb., 1934	411	121	85	617
April, 1934	16	70	106	192

* After a haul as many as possible of the shrimp were shaken from the net into a bucket. When the catch was too large to measure the total number taken, as in November, December, and February, a definite fraction (which always consisted of more than 100 shrimp) of the catch was taken as a sample and measured and the data arranged in a size-frequency distribution. The entries in these size-frequency distributions were then multiplied by the reciprocal of the fraction of the catch that was taken as a sample, thus bringing the distribution to an approximation of what it would have been if all of the shrimp shaken from the net had been measured. Many small shrimp remained in the net after it was shaken and, as we were particularly interested in these small individuals, all of them were measured, and these were added to the above mentioned calculated frequency distribution of shrimp shaken from the net thus giving a number which closely approximated the total catch. In Table 9 the percentages for November, December, and February were computed from length-frequency distributions determined in the above manner. For the other months all individuals taken were measured.

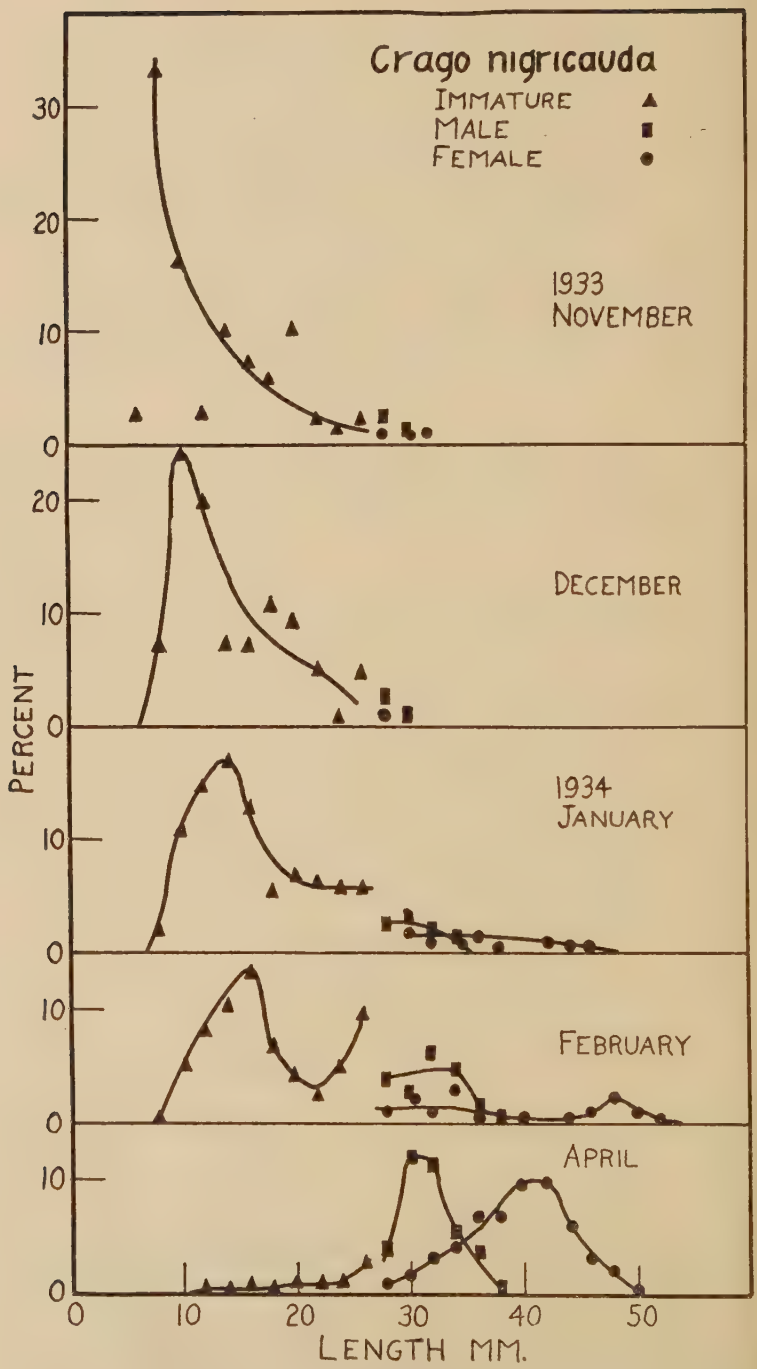

Fig. 7. *Crago nigricauda*, percentage length frequencies of young shrimp from south San Francisco Bay, November, 1933, to April, 1934.

viduals are simply referred to as "immature." In November, 1933, these immature shrimp are grouped closely about a modal size of approximately 8 mm. Only 2.6 per cent occur below the 8 mm. size group and the smallest of these is 5.9 mm. in length. This is the only month in this series of samples in which any young below 7.0 mm. were taken. Because many shrimp were between 7.0 and 7.9 mm., it would appear that the shrimp are 6.0 mm. to 7.0 mm. when they leave the last larval stage and acquire the post-larval characters.

TABLE 9

Percentage length frequencies of young *Crago nigricauda* from South San Francisco Bay, November, 1933, to April, 1934

Length in mm. (mid-value of class)	1933		1934		
	Nov.	Dec.	Jan.	Feb.	April
Immatures					
6.0	2.6%				
8.0	33.3	7.1%	1.9%	.3%	
10.0	16.3	24.3	10.8	5.2	
12.0	2.9	19.9	14.5	8.3	.5%
14.0	10.2	7.3	16.8	10.5	.5
16.0	7.2	7.1	12.8	13.6	1.0
18.0	5.9	10.6	5.3	7.0	.5
20.0	10.4	9.1	6.6	4.2	1.0
22.0	2.3	5.3	6.2	2.6	1.0
24.0	1.5	.8	5.6	5.0	1.0
26.0	2.3	4.6	5.6	9.9	2.6
Males					
28.0	2.3	2.3	2.3	3.9	3.7
30.0	.7	.8	3.0	2.6	12.0
32.0			1.6	6.3	11.5
34.0			1.0	4.9	5.2
36.0				1.5	3.7
38.0				.5	.5
Females					
28.0	.7	.8		1.0	1.0
30.0	.7		1.6	2.6	1.6
32.0	.7		.7	1.0	3.1
34.0			1.0	2.9	4.2
36.0			1.0	.5	6.8
38.0			.3		6.8
40.0				.5	9.9
42.0			.7		9.9
44.0			.3	.5	6.3
46.0			.3	1.0	3.1
48.0				2.4	2.1
50.0				1.0	.5
52.0				.5	

In December the modal length is very pronounced at 10 mm. and the range extends up to 31 mm. By January, 1934, the mode has advanced to 14 mm. and the range extends from 7.0 mm. to 35 mm. for the males and to 47 mm. for the females. Some of the larger individuals of both sexes taken in January may be from late spawning in the previous season. By April, 1934, there are sharp modes for the males and females at 31 and 41 mm., respectively. These shrimp will breed during the approaching spawning season. Some young shrimp as small as 11 mm. are still present in the catch.

Crago nigricauda is not found as far up the tidal portions of the Sacramento and San Joaquin rivers as is *C. franciscorum*. *C. nigricauda* occurs only in lower Suisun Bay in the autumn; whereas

C. franciscorum is found there throughout most of the year, and in the autumn occurs up as far as the mouth of Middle River, 35 miles above.

Commercial Catch

The commercial catch of the trawl fishermen does not furnish us with as satisfactory data on *Crago nigricauda* as on *C. franciscorum*. The fishermen usually follow the larger shrimp, *C. franciscorum*, so that their catch shows abrupt changes in the percentage of *C. nigricauda* taken. The following discussion is based upon monthly samples of the commercial catch of *C. nigricauda* as presented in Tables 10 and 11 and Figure 8. These data, with the exception of two samples from the Chinese fishermen at Hunters Point, have been taken from the catch of the trawl fishermen.

TABLE 10

Number and percentage of immature, male and female, *Crago nigricauda* from San Francisco Bay, August, 1931, to June, 1933

	Localities				Total number	Percentages		
	Flats	San Quentin	South-ampton	Hunters Point		Imma-tures	Males	Females
Aug., 1931	x				367	3.0	66.2	30.8
Sept., 1931		x			350	4.9	42.0	53.1
Oct., 1931	x				240	12.1	53.7	34.2
Nov., 1931	x				212	13.2	66.5	20.3
Dec., 1931	x				256	24.2	53.9	21.9
Jan., 1932	x				394	39.1	19.1	41.9
Jan., 1932		x			346	28.0	13.3	58.7
Feb., 1932	x				385	38.4	18.8	42.8
Feb., 1932		x			215	48.4	5.6	46.0
Mar., 1932	x				614	15.6	26.5	57.9
April, 1932			x		382	.5	49.2	50.3
May, 1932			x		343	4.7	45.8	49.5
June, 1932			x		358	15.6	45.0	39.4
July, 1932	x				125	20.0	3.2	76.8
July, 1932				x	203	.5	39.4	60.1
Aug., 1932	x				127	17.3	11.8	70.9
Aug., 1932				x	327	2.4	19.0	78.6
Sept., 1932	x				229	7.9	20.9	71.2
Oct., 1932				x	212	1.9	43.4	54.7
Oct., 1932		x			287	4.5	29.6	65.9
Nov., 1932	x				118	42.4	29.6	28.5
Nov., 1932		x			86	1.2	43.0	55.8
Dec., 1932	x				174	1.7	70.7	27.6
Jan., 1933	x				238	11.4	55.0	33.6
Feb., 1933	x				159	1.2	47.2	51.6
Mar., 1933	x				340	15.3	50.3	34.4
April, 1933	x				191	25.6	35.1	39.3
May, 1933	x				130	38.5	37.7	23.8
May, 1933			x		79	0.0	70.9	29.1
June, 1933			x		145	6.9	43.4	49.7
Grand total					7,632			

In September, 1931, the range extends down to 23 mm. The males and females show definite modes at 32 and 40 mm., respectively. Breeding activities are still in full swing, 70 per cent of the mature females being ovigerous.

On the other hand in February of 1932 the immature group extends its range down to 11 mm. and comprises 41 per cent of the catch. The modal lengths for both the males and females are at 30 mm. or less. Breeding activity is at its lowest point of the year, less than 10 per cent of the mature females being ovigerous. These data may be

TABLE 11

Percentage length frequencies of *Crago nigricauda* from San Francisco Bay, August, 1931, to June, 1933

	1931					1932												1933					
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June
Localities—																							
Southampton									x	x	x											x	x
San Quentin	x	x				x	x						x	x	x	x						x	
Flats			x	x	x	x	x	x				x	x			x	x	x	x	x	x		
Hunters Pt.												x			x								
Length in mm. (mid-value of of class)																							
Immatures																							
12.0			.4%			.3%	.3%						.4%			.5%		.4%				.5%	
14.0			.4			.1	1.2																
16.0						.8	1.7					.3%	.7		.2%	1.5		2.1			.5%	1.0	1.9
18.0			.4	1.4%	1.2%	3.4	3.2	.3%		.6%	.8%		.4	.9%	.2	.5		1.3	.6%	.3%	4.7	1.4	
20.0			.8	1.4	1.9	3.9	5.5	1.8		.6	1.9	.3	.9	1.3		1.5		1.7		1.5	4.2	2.9	
22.0				4.7	2.7	8.3	9.2	2.3		.9	2.5	2.1	.9			7.8	1.1%	2.1	.6	2.3	6.3	5.7	1.4%
24.0	1.1%	1.2%	3.7	3.3	7.4	8.5	9.8	4.0		1.7	4.7	3.0	.9	2.6	.8	7.3		1.7		5.0	3.1	4.8	.7
26.0	1.9	3.7	6.2	2.4	10.9	8.7	11.2	7.3	.5%	.9	5.6	2.1	2.4	3.1	2.2	5.9	.6	2.1		6.2	5.8	6.7	4.8
Males																							
28.0	4.4	4.6	11.7	3.8	8.6	3.5	3.8	5.2	2.1	.9	3.6	1.5	3.3	1.7	2.8	5.9	2.3	5.5	1.3	8.8	4.2	1.4	.7
30.0	17.7	7.4	12.1	12.7	9.0	2.8	3.2	6.3	6.0	1.4	8.1	3.3	2.9	.4	7.8	6.9	9.8	5.0	1.9	7.3	10.5	7.2	4.8
32.0	22.3	13.2	17.1	18.0	16.4	3.3	4.0	7.0	16.5	7.0	8.1	4.6	5.3	3.9	7.0	9.8	12.1	11.4	11.3	7.9	11.0	8.6	6.2
34.0	16.1	11.2	10.0	20.7	13.7	4.3	1.5	3.9	16.0	16.3	10.1	3.7	3.5	8.3	8.2	7.8	20.1	11.4	13.2	8.2	8.9	13.4	6.9
36.0	4.4	5.1	1.2	8.0	4.3	1.9	1.0	2.8	5.0	14.9	12.6	4.6	.9	4.4	6.6	2.9	13.8	13.5	10.1	11.5	.5	13.9	13.8
38.0	1.4	.6	1.7	3.3	1.6	.5	.3	.8	3.1	4.4	1.4	4.0	.7	2.2	3.0	1.5	9.8	7.1	6.9	5.6		4.3	9.0
40.0					.4		.2	.2	.3	.6	1.1	4.0	.4			.5	1.7	.8	1.3	.6		1.4	2.1
42.0										.3							1.1	.4	1.3				
44.0								.2	.3											.3			
Females																							
28.0	.5	.8	2.5	1.4	2.7	5.1	7.2	5.0	1.0	1.2	1.4	2.4	1.8	1.3	1.8	2.4	.6	.8	.6	2.1	3.1	2.9	2.1
30.0	2.2	1.2	2.9	.5	2.7	6.8	8.8	8.1	1.0	.6	1.7	2.1	3.5	1.7	3.0	1.5	2.3	1.3	1.3	4.7	2.1	.5	.7
32.0	2.4	2.6	6.7	.9	5.5	6.6	6.2	8.5	2.6	.9	1.4	4.0	3.7	2.6	5.6	5.9	.6	.8	.6	2.3	1.6	.5	.7
34.0	3.5	3.4	2.9	4.3	1.2	5.6	3.5	8.3	4.2	.6	.8	4.6	4.6	3.5	6.4	2.9	1.1	3.4		.9	2.6	1.4	.7
36.0	2.7	4.0	1.7	1.4	1.9	4.6	5.2	6.3	6.3	.9	.8	4.3	4.8	6.1	6.2	4.4	1.1	3.8	1.9	2.1	5.8	.5	
38.0	4.6	6.3	4.6	2.8	1.9	3.9	3.8	4.2	6.0	1.4	.6	6.7	7.5	5.7	7.6	3.9	2.3	6.7	2.5	2.1	5.8	1.0	
40.0	3.8	10.8	2.5	1.9	1.6	4.1	4.0	5.9	4.4	1.4	1.4	4.9	9.9	5.7	6.8	6.4	1.7	2.9	7.5	2.3	7.3	2.4	1.4
42.0	3.3	9.1	4.2	4.7	1.2	3.9	1.3	3.1	3.9	4.7	3.6	7.0	13.2	10.5	7.4	3.9	6.3	4.6	10.1	2.9	4.2	1.9	.7
44.0	3.8	8.6	3.3	.9	1.9	2.8	2.0	3.4	6.3	9.3	3.6	7.0	12.1	14.4	6.6	3.9	4.0	2.5	10.1	3.8	3.7	4.3	4.1
46.0	1.1	4.0	1.2	.9	1.2	2.7	.7	2.6	4.2	10.2	7.5	5.5	8.8	7.9	4.8	1.5	2.9	4.2	8.2	5.0	2.1	1.9	6.9
48.0	1.6	.8	1.2	.5		2.0	1.0	1.9	4.2	9.6	6.7	5.8	3.7	9.2	3.2	1.5	1.7	1.3	6.9	2.9	.5	4.3	14.5
50.0	1.1	.8	.4			.8	.3	.3	3.1	4.1	6.1	5.2	1.1	2.6	1.2	1.5	1.1		1.3	2.3		2.4	9.6
52.0		.3				.5		.2	2.4	2.9	2.2	5.5	1.1		.4		.6	.8	.6	.6	.5	1.0	4.1
54.0		.3				.1			.5	1.2	.6	.9					1.1	.4				1.0	1.4
56.0						.1				.3		.6	.2							.3			.7
58.0											.6		.2										1.4
60.0																							
62.0										.3	.3												.7

interpreted as showing that the bulk of the catch is now made up of an incoming age group which first appeared in November or December.

By May, 1932, the spawning season is well under way, 62 per cent of the mature females being ovigerous. The males show a modal length at 35 mm., the females at 46 mm. This difference of 11 mm. or nearly 25 per cent results from a differential growth rate which began at an early age.

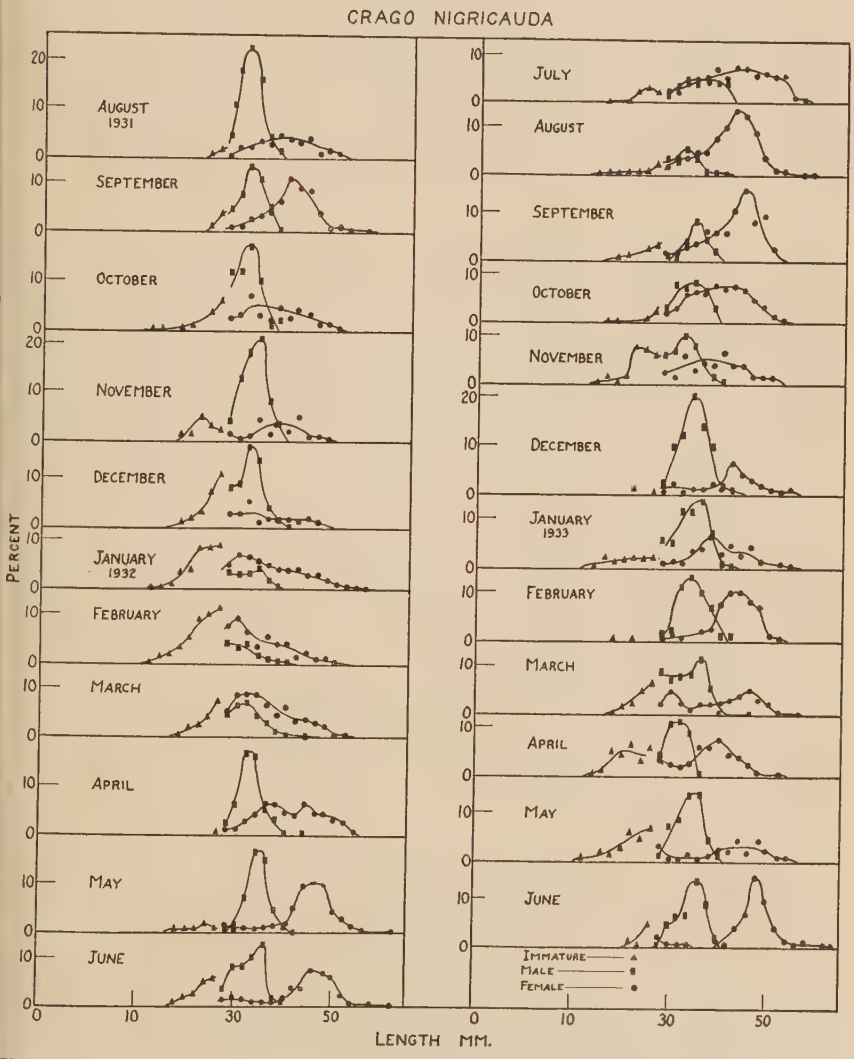

Fig. 8. *Crago nigricauda*, percentage length frequencies from San Francisco Bay, August, 1931, to June, 1933.

Our data seem to indicate that the breeding population of April to September comes from the previous year's spawning, and that they disappear from the commercial catch between October and December of the same year. Consequently the range in size is very extended, and

sharply defined modes do not often appear. The movement of the shrimp and the changing localities in which the fishermen operate undoubtedly mask the actual progression of the modal lengths.

Ehrenbaum (1890) considered that *Crago vulgaris* might reach an age of four years and that the large females of 70-76 mm. are not less than three years old. The data for both *Crago franciscorum* and *C. nigricauda* indicate that either species could attain its maximum size in a single year, and that if any individuals remain in the catch past this time they show very little growth.

The ratios of male, female, and immature of *Crago nigricauda* are given in Table 10. These data fail to show any cyclic rhythm. Perhaps a series from one locality throughout the year or from changing localities, which corresponds to the movements of the shrimp population, would show a periodic rhythm in the occurrence of the sexes.

COMPOSITION OF THE COMMERCIAL CATCH

Although casual inspection of the catches gives the impression that *Crago franciscorum* forms the bulk, a careful analysis shows that *C. nigricauda* is of more importance than one is at first led to believe. Table 12 and Figure 9 give the computed weights of the two species taken by the trawl fishermen in District 12 between August, 1931, and June, 1933. This figure was obtained by weighing the amounts of *Crago franciscorum* and *C. nigricauda* present in one to three samples and computing the month's catch on this basis. It is realized that this is only a rough estimate of the true figures, as the ratio between the two species varies from day to day and between different fishermen on the same day. However, this method does give us an impersonal approximation of the size of the catch of each species that is much better than an estimate resulting from visual impressions. *Crago nigromaculata* has not been considered in making these estimates because it usually does not appear in the catch at all and never in sufficient quantities to alter these figures appreciably.

The 1932 catch of *Crago franciscorum* remains at a low level until July when a sharp advance nets 139,700 pounds. From a peak of 185,400 pounds in August, there is a decline to 77,400 pounds in November. From December, 1932, to June, 1933, the catch remains below 40,000 pounds.

The catch of *Crago nigricauda* increases sharply in April, 1932, to 80,400 pounds. From then to and including September, with the exception of July, the catch remains high. Between October, 1932, and June, 1933, the yield in any one month remains below 30,000 pounds.

The 1932 catch of 794,700 pounds of *Crago franciscorum* is approximately one and a half times that of *C. nigricauda.* Between August and December, 1931, the yield of 359,100 pounds of *C. nigricauda* is nearly three times that of *C. franciscorum,* whose peak is reached in October with only 58,800 pounds.

In 1933, between January and June, the catch of *C. franciscorum* is nearly three times that of *C. nigricauda,* but the yield of either species is small, being 96,100 and 35,300 pounds, respectively.

TABLE 12

Composition of the commercial catch of shrimp in District 12

	Percentage of catch (by weight)		Catch in pounds	Approximate weight of *C. franciscorum*	Approximate weight of *C. nigricauda*
	C. franciscorum	*C. nigricauda*	1931		
August	5.9	94.1	208,673	12,300	196,400
September	49.2	50.8	51,781	25,400	26,400
October	35.0	65.0	168,093	58,800	109,200
November	69.2	30.8	42,107	29,100	12,900
December	29.2	70.8	20,095	5,870	14,200
Totals			490,749	131,470	359,100
			1932		
January	81.9	18.1	26,208	21,500	4,700
February	57.6	42.4	26,860	15,500	11,400
March	35.9	64.1	51,094	18,300	32,800
April	8.6	91.4	87,934	7,600	80,400
May	24.1	75.9	120,619	29,100	91,500
June	34.6	65.4	111,812	38,700	73,100
July	81.7	18.3	171,029	139,700	31,300
August	70.5	29.5	263,014	185,400	77,600
September	57.4	42.6	238,910	137,100	101,800
October	76.7	23.3	119,561	91,700	27,600
November	87.1	12.9	88,905	77,400	11,500
December	88.8	11.2	36,805	32,700	4,100
Totals			1,342,751	794,700	547,800
			1933		
January	90.2	9.8	18,128	16,300	1,800
February	89.0	11.0	43,309	38,600	4,700
March	80.3	19.7	15,329	12,300	3,000
April	67.1	32.9	14,244	4,700	9,500
May	64.9	35.1	8,135	5,300	2,800
June	58.2	41.8	32,420	18,900	13,500
Totals			131,565	96,100	35,300

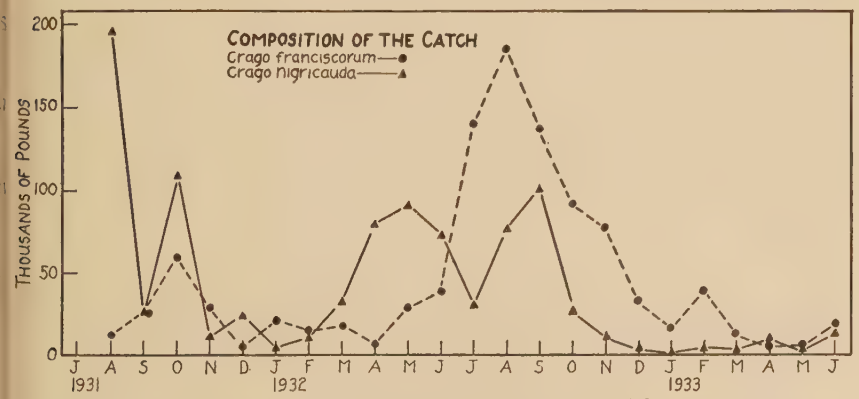

Fig. 9. Composition of the commercial catch.

With the exception of October, 1931, all of the large catches of *Crago nigricauda* were made either at San Quentin or Southampton. In April, 1932, when fishing operations moved from the Flats to Southampton, the catch of *C. nigricauda* advanced from 32,800 pounds to

80,400 pounds. In July, when the fishermen worked on the Flats, the yield dropped off heavily, to be regained in August, when most of the fishing was done at San Quentin. Of the three samples in the August catch, one from the Flats gave only 18 per cent *C. nigricauda,* and two from San Quentin gave more than double this amount. All of the catches of *C. franciscorum* taken at Southampton were small. Southampton is the locality nearest the ocean; the Flats are at the greatest distance from it.

In 1932, the large catch of *Crago franciscorum* was made after the end of the breeding season for that species. In contrast to this, the heavy yield of *C. nigricauda* between April and September corresponds exactly with the breeding season. It is interesting to speculate on what effect this will have on future catches. In May and June of 1933, when fishing operations moved to Southampton, the expected large increase in the catch of *C. nigricauda* did not occur. Might this have been due to the heavy inroads made during the preceding spawning season?

SUMMARY

Much of the life histories of *Crago franciscorum* and *C. nigricauda* are very similar. They move toward the ocean as the spawning season approaches, and the eggs hatch in water of high salinity.

The young shrimp are found at some distance from the ocean in shallow water of reduced salinity. As they grow, they move into deeper water, gradually entering the commercial catch.

Some females of both species undoubtedly spawn twice, the second set of eggs being laid soon after the first set hatches.

In both species a differential growth rate sets in at an early age. The females grow more rapidly than the males, attaining a size about 25 per cent larger. Average lengths for adult male and female *C. franciscorum* are about 45 and 60 mm., respectively; for adult male and female *C. nigricauda* about 35 and 45 mm.

Both species breed at the end of their first year and soon afterward disappear from the commercial catch.

Ovigerous females of either species can be found throughout the year. The main breeding season for *Crago franciscorum* extends from December to May or June, inclusive, and that of *C. nigricauda* lasts at least six months, from April to September.

Only in the fall can *Crago nigricauda* be found in lower Suisun Bay. *Crago franciscorum* occurs here throughout the year and in the fall extends up the lower San Joaquin River to within 15 miles of Stockton.

Crago nigromaculata is of little importance in the commercial catch.

The catch of *Crago franciscorum* between August, 1931, and June, 1933, in District 12 slightly exceeded that of *Crago nigricauda.*

The large catch of *C. franciscorum* in 1932 was made after the breeding season had ended. The large catch of *C. nigricauda* in 1932 corresponded exactly with the breeding season. This may have an important effect upon the catch of succeeding years.

Both species are taken abundantly at San Quentin. Toward the ocean from this point only *Crago nigricauda* is found in large numbers. Farther inland *Crago franciscorum* is usually the only species occurring in abundance.

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